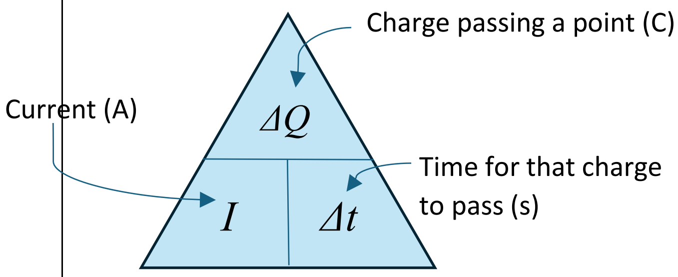
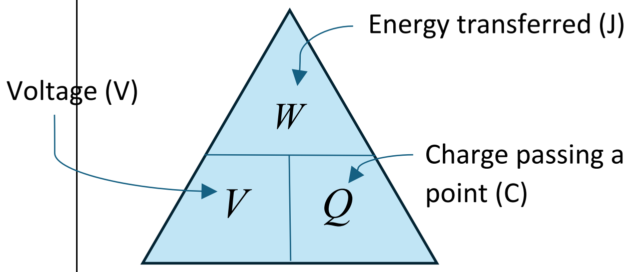
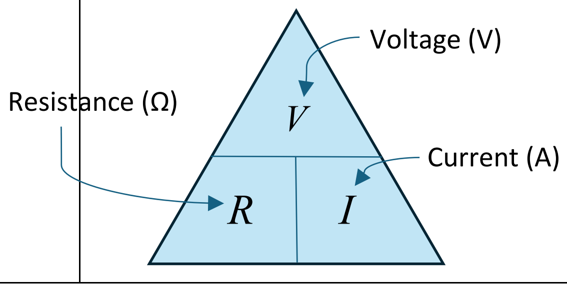
2.4 Electric Circuits

This topic covers the definitions of various electrical quantities, for example current, potential difference and resistance, Ohm's law and non-ohmic conductors, potential dividers, e.m.f. and internal resistance of cells and negative temperature coefficient thermistors.

This topic should be studied using applications such as space technology.

This unit includes many opportunities for developing experimental skills and techniques by carrying out more than just the core practical experiments.

Candidates will be assessed on their ability to:

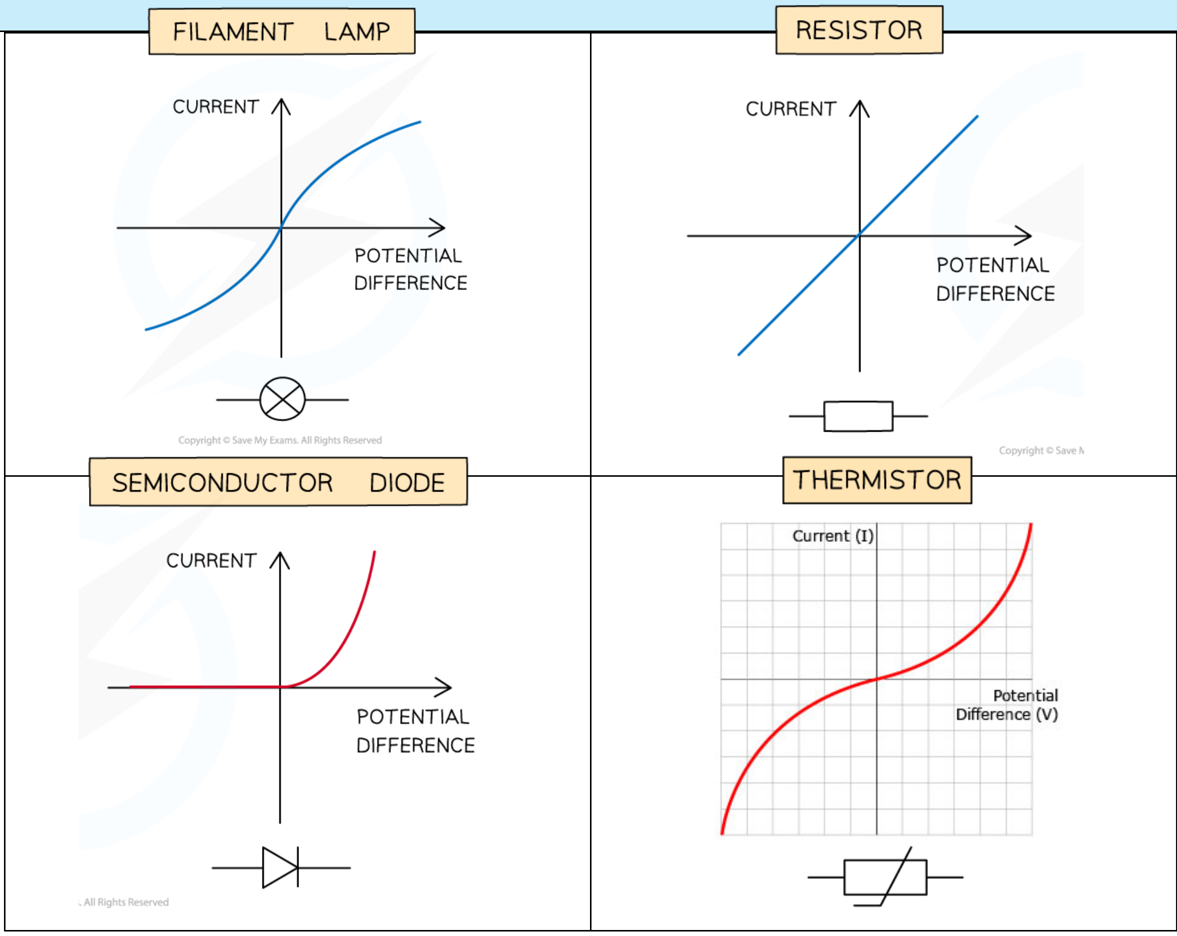
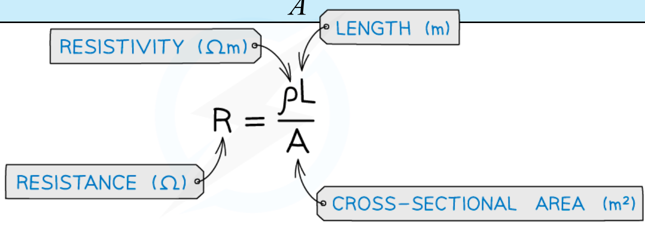
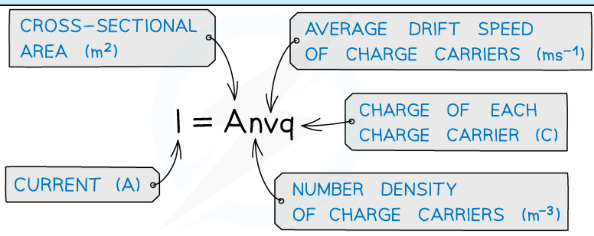
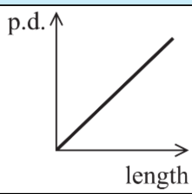
64	understand that electric current is the rate of flow of charged particles and be able to use the equation $I = \dfrac{\Delta Q}{\Delta t}$
	 **Electric current** is the rate of flow of charged particles
65	understand how to use the equation $V = \dfrac{W}{Q}$
	 **Voltage** is the energy transferred per unit charge
66	understand that resistance is defined by $R = \dfrac{V}{I}$ and that Ohm's law is a special case when $I \propto V$ for constant temperature
	 **Resistance** is the opposition to the flow of current Ohm's law states that the current through a component is directly proportional to the voltage across it, provided that the temperature remains constant ***V = IR***

67	(a) understand how the distribution of current in a circuit is a consequence of charge conservation (b) understand how the distribution of potential differences in a circuit is a consequence of energy conservation
(a)	The total amount of charge within a circuit cannot increase or decrease while the circuit is functioning due to conservation of charge At a junction, current will split (current is more likely to take the path with the lesser resistance) and when they join up again, Sum of current entering a junction = Sum of current leaving a junction
(b)	In a closed-circuit loop (series circuit), Total sum of emfs = Total sum of potential difference around that loop Due to the law of conservation of energy, energy is never used up or lost in a circuit
68	be able to derive the equations for combining resistances in series and parallel using the principles of charge and energy conservation, and be able to use these equations

Formula Derivation for R_{total} in Series	Formula Derivation for R_{total} in Parallel
In series circuit, $V_{total} = V_1 + V_2$ Current is the same throughout $\Rightarrow$ $IR_{total} = IR_1 + IR_2$ $\cancel{I}R_{total} = \cancel{I}(R_1 + R_2)$ $R_{total} = R_1 + R_2$	In parallel circuit, $I_{total} = I_1 + I_2$ $\frac{V}{R_{total}} = \frac{V_1}{R_1} + \frac{V_2}{R_2}$ Voltage is same in parallel so $\div V \Rightarrow \frac{1}{R_{Total}} = \frac{1}{R_1} + \frac{1}{R_2}$

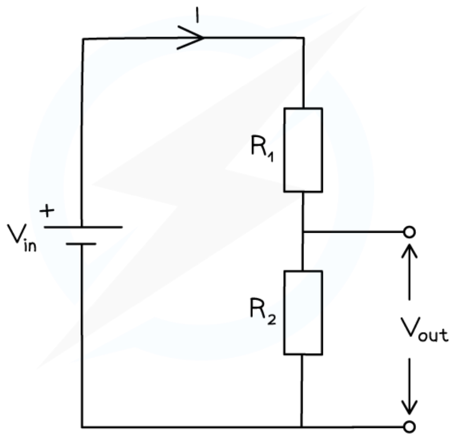
Quantity	Series Circuit Rules	Parallel Circuit Rules
Current	Current is the same throughout	$I_{total} = I_1 + I_2$
Voltage	$V_{total} = V_1 + V_2$	Voltage is the same on each branch
Resistance	$R_{total} = R_1 + R_2$	$\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2}$

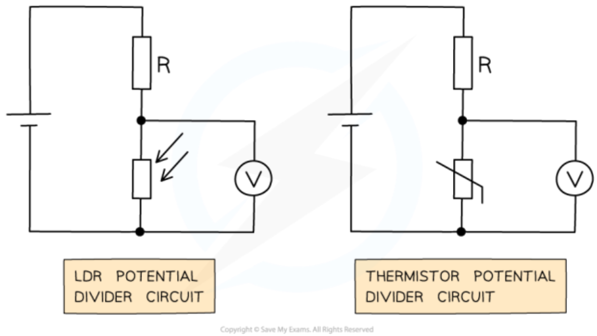
69	be able to use the equations $P = VI$, $W = VIt$ and be able to derive and use related equations, e.g. $P = I^2R$ and $P = \frac{V^2}{R}$

70	understand how to sketch, recognise and interpret current-potential difference graphs for components, including ohmic conductors, filament bulbs, thermistors and diodes
	
71	be able to use the equation $R = \frac{\rho l}{A}$
	
72	**CORE PRACTICAL 7: Determine the electrical resistivity of a material**
73	be able to use $I = nqvA$ to explain the large range of resistivities of different materials
	
74	understand how the potential along a uniform current-carrying wire varies with the distance along it
	At a constant temperature, as the length of a uniform conductor increases, resistance also increases As V=IR, as R increases, V also increases Hence, potential difference across a uniform wire is directly proportional to its length 

75	understand the principles of a potential divider circuit and understand how to calculate potential differences and resistances in such a circuit

POTENTIAL DIVIDER EQUATION: $V_{out} = \frac{R_2}{R_1 + R_2} V_{in}$



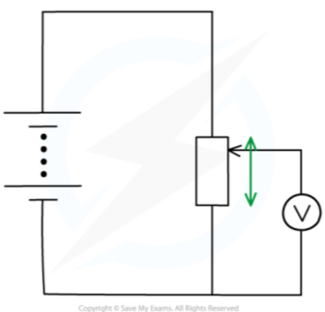
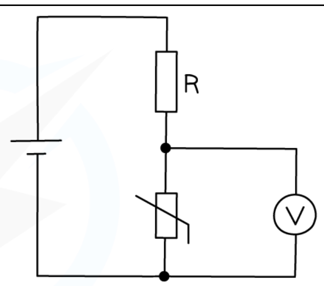
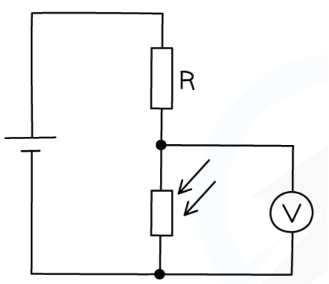


Potential dividers are circuits that divide voltage of the power supply in a certain ratio using two resistors in series

If the resistance of one of the resistors is increased, the potential difference across that resistor will increase whilst the potential difference across the other resistor will decrease

We can also link the ratio of p.d. and resistance across each resistor using: $\frac{V_1}{V_2} = \frac{R_1}{R_2}$

76	be able to analyse potential divider circuits where one resistance is variable including thermistors and light dependent resistors (LDRs)

	<u>Potentiometer</u> If the slider in the diagram is moved upwards, the resistance of the lower part will increase and so the potential difference across it will increase
	<u>Thermistor</u> When temperature increases, resistance of thermistor decreases, the potential difference across the thermistor also decreases which means the potential difference across the other resistor increases
	<u>Light Intensity</u> When light intensity increases, resistance of LDR decreases, the potential difference across the LDR also decreases which means the potential difference across the other resistor increases

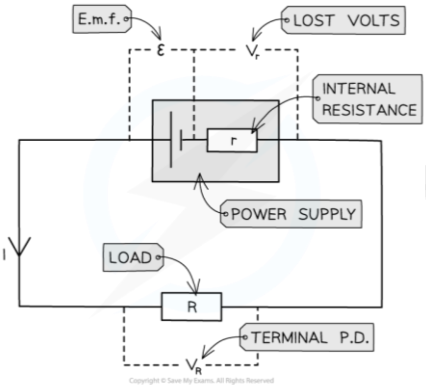
77 know the definition of *electromotive force (e.m.f.)* and understand what is meant by *internal resistance* and know how to distinguish between e.m.f. and *terminal potential difference*

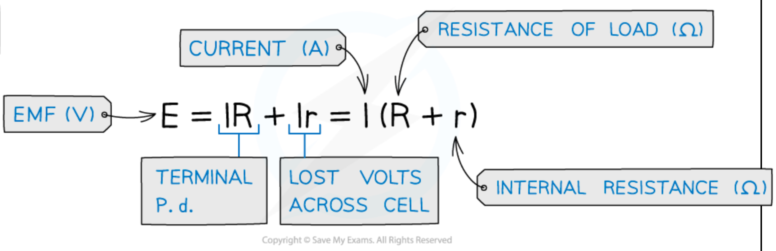
E.m.f. isn't actually a force but rather a measure of energy transferred per charge (measured in volts)

Electromotive force is defined as:
"The amount of chemical energy converted into electrical energy per unit charge (when charge passes through a power supply)"

In essence, electromotive force is the work done moving a unit charge around the whole circuit

Internal resistance is the resistance of an e.m.f. source





78 **CORE PRACTICAL 8: Determine the e.m.f. and internal resistance of an electrical cell**

79 understand how changes of resistance with temperature may be modelled in terms of lattice vibrations and number of conduction electrons and understand how to apply this model to metallic conductors and negative temperature coefficient thermistors

All materials have some resistance to the flow of charge
This is because as free electrons move through a wire, they collide with the metal ions, losing energy as heat

As temperature increases, the vibrations of the ions in the lattice also increase which increases the rate of collisions between free electrons and metal ions. Drift velocity of electrons decreases which results in a decrease in current. As V = IR, a decrease in current causes an increase in resistance
That is why too high a current will cause an increase in temperature and thus an increase in resistance

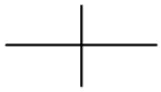
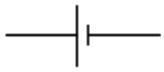
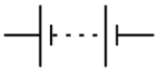
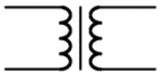
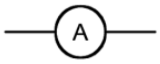
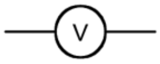
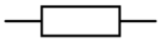
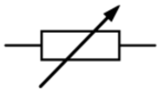
For metallic conductors,
As temperature increases, resistance (and resistivity) increases and current decreases
As temperature decreases, resistance (and resistivity) decreases and current increases

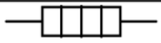
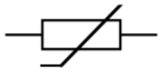
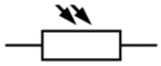
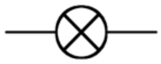
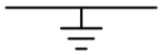
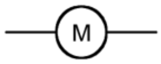
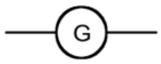
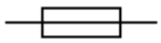
For semiconductors (thermistors),
As temperature increases, the number density of charge carriers (electrons) increases, i.e. the number of conduction electrons per unit volume increases which results in a decrease in resistance (and resistivity)

80 understand how changes of resistance with illumination may be modelled in terms of the number of conduction electrons and understand how to apply this model to LDRs

As the light intensity falling on an LDR increases, more electrons are moved from the valence band to the conduction band which leads to an increase in conduction electrons which in turn results in a decrease in resistance of LDR

Electrical circuit symbols

Description	Symbol
Conductors crossing with no connection	
Junction of conductors	
Open switch	
Cell	
Battery of cells	
Power supply (DC)	
Power supply (AC)	
Transformer	
Ammeter	
Voltmeter	
Fixed resistor	
Variable resistor	

Description	Symbol
Heater	
Thermistor	
Light-dependent resistor (LDR)	
Diode	
Light-emitting diode (LED)	
Lamp	
Loudspeaker	
Microphone	
Electric bell	
Earth or ground	
Motor	
Generator	
Fuse/circuit breaker	

Although these are the forms of circuit symbols that will be used in examination papers, there may be other internationally agreed symbols that are acceptable in student answers.

Remarks

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  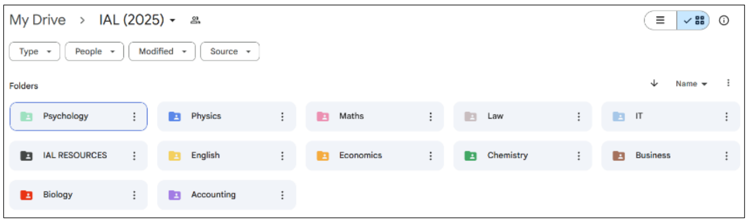

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